Exercise Testing and Training in Patients With Peripheral Vascular Disease and Lower Extremity Amputation

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Patients with peripheral vascular disease have a high risk of coronary artery disease. The risk is even greater when the peripheral vascular disease leads to lower extremity amputation. Exercise testing using lower extremity exercise has been the "gold standard" for screening for coronary artery disease, but many patients with peripheral vascular disease and those with amputations have difficulty doing this type of exercise. Arm exercise ergometry has been shown to be a safe and effective alternative for the detection of coronary artery disease in patients who cannot do leg exercise. This test has also been used to determine safe exercise levels and may be able to predict the ultimate level of prosthetic use in amputees. Exercise training with arm ergometry also improves cardiovascular efficiency and upper body strength in poorly conditioned patients. Studies are needed to appreciate fully the role of exercise testing and training in the recovery of these patients after amputation.

(Priebe M, Davidoff G, Lampman RM: Exercise testing and training in patients with peripheral vascular disease and lower extremity amputation, *In* Rehabilitation Medicine—Adding Life to Years [Special Issue]. West J Med 1991 May; 154:598-601)

Patients with peripheral vascular disease (PVD) have a high prevalence of coronary artery disease.[1-4] Patients who require peripheral revascularization are at an increased risk for cardiac complications including silent ischemia, myocardial infarction, arrhythmia, and death from coronary artery disease.[1,3]

Cutler reported that the prevalence of severe coronary artery disease in patients with PVD is greater than 50%.[3] He concluded that myocardial infarction is the most common cause of early and late postoperative morbidity among patients requiring surgical management of PVD. Risk factors associated with postoperative cardiac events include myocardial infarction six months before surgical therapy, congestive heart failure, ventricular dysrhythmia, previous stroke, and an abnormal resting electrocardiogram (ECG). These risk factors were consistent with those reported by Cooperman and co-workers.[1]

Many investigators have tried to find ways to screen patients with PVD who require a peripheral vascular operation, in an attempt to decrease cardiac morbidity and mortality associated with surgical procedures. These screening methods have included an inventory of risk factors, graded exercise stress testing, and dipyridamole-thallium (D-T) imaging.

Exercise testing using a treadmill has been the "gold standard" for assessing cardiac ischemia in symptomatic and asymptomatic patients. It has been used by many physicians to predict those who will have cardiac complications after a peripheral vascular operation.[2,3]

McCabe and associates reviewed the value of ECG monitoring during treadmill testing for PVD patients.[2] They found that in 44% of 150 patients with a recent history of coronary artery disease, myocardial infarction, or angina, ECG changes developed during testing. They noted that 26% of 125 unselected PVD patients with no documented history of cardiac disease had similar exercise-induced ECG changes develop. They concluded that ECG monitoring with treadmill testing was a good screen for cardiac ischemia in asymptomatic patients with PVD. Similar findings have been reported by Cutler and colleagues.[5]

Eagle and co-workers described the use of D-T imaging to improve preoperative cardiac evaluation in PVD patients before lower extremity revascularization.[4] With this imaging technique, patients are not required to do any exercise. Eagle and colleagues studied 61 patients with preoperative D-T imaging. The presence of thallium Tl 201 redistribution following the intravenous administration of dipyridamole was associated with a 45% increased risk of perioperative complications. They concluded that D-T imaging was useful for stratifying patients at increased risk for cardiac complications who have one or more clinical cardiac symptoms.

McPhail and associates compared exercise stress testing with D-T imaging for predicting perioperative cardiac complications in vascular reconstruction patients.[6] They studied 60 patients who underwent aortic aneurysm or aortoiliac reconstruction with both treadmill exercise or arm ergometry and D-T imaging. Exercise stress testing had a sensitivity of 0.23 with specificity of 0.89, whereas D-T imaging had a sensitivity of 0.86 with specificity of 0.68. They concluded that D-T imaging was a superior screen for cardiac disease in patients with PVD. The low sensitivity of exercise stress testing in these patients was felt to be due to the inability of many patients to generate a sufficient cardiac workload to trigger ischemia.

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Funding for this project was provided by a Research Training Grant from the National Institute on Disability and Rehabilitation Research, US Department of Education (H133P80037), and the US Department of Veterans Affairs, Washington, DC. The following staff helped develop the exercise testing and training program at our institution: Leslie Westbury, Jacqueline Deron, MS, J. Steven Schultz, MD, Hillel M. Finestone, MD, and Sue Hazel.

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ABBREVIATIONS USED IN TEXT

D-T = dipyridamole-thallium
ECG = electrocardiogram
PVD = peripheral vascular disease
RPE = rate of perceived exertion
THR = training heart rate

Cardiovascular Disease in Patients With Amputation for Peripheral Vascular Disease

The prevalence of severe coronary artery disease and associated postoperative cardiac complications in patients with severe PVD is high. Likewise, severe cardiac disease is equally prevalent in vascular amputees admitted for rehabilitation and prosthetic training. Methods of detecting coronary artery disease previously discussed for PVD patients are readily applicable for screening vascular amputees before initiating exercise training and rehabilitation. In addition, ECG monitoring during physical therapy and prosthetic training has been used to evaluate the cardiac status of patients with lower extremity amputation.

Perlman and colleagues reported the use of dynamic ECG (Holter) monitoring during rehabilitation and prosthetic training of 65 elderly patients with unilateral amputation.[7] Cardiac status was evaluated by history, physical examination, chest radiograph, laboratory profile, and resting ECG. A ten-hour ECG monitoring was also performed during routine activities in physical therapy. Various ECG changes during prosthetic training were noted. The most significant and stressful event was single-legged hopping while holding onto parallel bars. Kohn further analyzed Perlman's original cohort and reported that 41 of 58 (70%) had evidence of cardiac disease on admission and that those patients without heart disease progressed more rapidly in their prosthetic training program.[8] These authors concluded that the high prevalence of cardiac disease required modification of the customary training program among elderly amputee patients to safely complete a prosthetic training program.

Kavanaugh and Shephard studied 62 patients admitted for rehabilitation after amputation for PVD.[9] Of the 62, 30 (48%) had a history of myocardial infarction or congestive heart failure, 10 additional patients had diastolic hypertension, and 28 of 60 (47%) had an abnormal resting ECG. In 18 of 27 patients (67%) who underwent exercise stress testing using an arm ergometer, ST segment depression of greater than 1 mm developed. Half of those with exercise-induced ECG changes had previously been asymptomatic and had a normal resting ECG. Exercise-induced ECG changes occurred at moderate workloads (< 50 watts per minute), indicating advanced coronary artery disease. It was concluded that exercise testing could be used to define the limits of safe exercise in this patient population. Similar rates for dynamic ECG abnormalities during exercise stress testing in this population have been documented by Cruts, Finestone, and Davidoff and co-workers.[10-12]

Roth and associates published a report of 31 patients admitted for amputee rehabilitation who were monitored during routine physical therapy sessions for heart rate, blood pressure, and ECG changes.[13] The mean age was 65 years. Of the 31, 17 (55%) had cardiac problems detected by monitoring ECG and vital signs. Four of these patients had no history of cardiac disease. They also found that a history of congestive heart failure, digoxin use, or a delay in admission to rehabilitation of greater than 14 days was closely related to the finding of cardiac problems during monitoring. They concluded that the combination of screening for a history of coronary artery disease and dynamic cardiac monitoring provided the most useful information for detecting cardiac disease in this population.

Van Alsté and colleagues reported the use of symptom-limited exercise testing in patients with lower extremity amputation.[14] They admitted 39 subjects, with a mean age of 67 years, for a prosthetic training program. Of the 39 subjects, 21 (54%) had previous cardiac problems or abnormal resting ECGs. In all, 37 of the patients were studied with graded exercise tests using an arm ergometer. The mean peak workload was 63 watts per minute, and the mean peak heart rate was 124 beats per minute. In 14 of the 37 patients (38%), ST segment depression of more than 1 mm was seen at peak workloads. Five patients showed similar changes at rest. The reasons for terminating the exercise testing included general fatigue (59%), an inability to maintain the rotational speed (23%), and arm and muscle fatigue (18%). None terminated because of chest pain. Similar reasons for terminating exercise stress testing in this patient population have been noted by Finestone and Davidoff and co-workers.[11,12] It was concluded that cardiac problems were common in elderly vascular amputees and that exercise testing was able to detect previously unrecognized cardiac abnormalities. Arm ergometry can also be used to determine safe maximal heart rates for exercise and provide guidelines for the rehabilitation program.

Exercise Training in Patients With Peripheral Vascular Disease or Amputation

Pitetti and associates reported the use of a 15-week aerobic training program in 20 long-term traumatic amputees.[15] Each person was tested using a treadmill stress testing protocol before beginning the exercise training program. Each subject then exercised independently using a Schwinn Air-Dyne ergometer as directed by the training protocol. Only 10 (50%) completed the entire training program. Those who completed the training protocol had a 25% increase in their maximum work capacity. The authors also found a decreased heart rate at submaximal exercise, an increased heart rate at peak exercise, and improved peak oxygen consumption. They concluded that aerobic conditioning improved the cardiovascular fitness and economy of walking in patients with lower extremity amputations.

Previous work from our laboratory resulted in an exercise testing and training program using arm ergometry.[12] This program is used in conjunction with standard rehabilitation for patients with recent vascular amputation who are profoundly deconditioned after complicated perioperative courses. Our protocol is simple to administer and inexpensive. Patients first have a baseline resting ECG. During exercise, a bipolar V_5 lead is used for monitoring arrhythmias and ST segment depression. Patients exercise using an arm crank ergometer in three-minute stages. The resistance begins at 5 watts and is increased by 5-watt increments per stage. Patients exercise for 2 minutes 30 seconds and then crank at zero resistance for 30 seconds so that blood pressure and artifact-free ECG rhythm strips can be recorded. Testing is terminated if a patient's systolic blood pressure drops progressively with increased work, if clinically significant cardiac arrhythmias occur, if the patient loses the capacity to maintain a steady cranking rate of 50 rpm, and for limb fatigue, angina, or dyspnea.

The training heart rate (THR) for patients is then calculated using Karvonen's formula[16] at a 50% intensity, as given in the following equation:

$$\text{THR} = \text{resting HR} + ([\text{maximal HR} - \text{resting HR}] \times 0.50).$$

While the initial intensity is established at 50%, the goal is to reach an intensity of 70% as patients become better conditioned. Patients initially do interval arm ergometry exercise training using this THR for a total of 15 minutes of aerobic exercise per session. For example, if the THR of 130 beats per minute was associated with a power output of 10 watts per minute for a specific patient, the patient would train as follows: warm-up at no resistance (5 minutes), cycle at 5 watts (5 minutes), cycle at 10 watts (5 minutes), cycle at 5 watts (5 minutes), and a cool-down phase of five minutes consisting of cranking at 0 watts. As the patient's exercise tolerance improves, the duration of cycling at 10 watts would increase until all 15 minutes of aerobic activity could be spent comfortably at 10 watts. At this point the target intensity would be increased to 60% and, if sufficient progress allowed, to 70% using these guidelines. This program is accompanied by morning and afternoon sessions of progressive resistance exercise for major muscle groups of the upper and lower extremities and functional training with a prosthesis when clinically appropriate. This program is conducted five times a week.

So far 25 patients, with a mean age of 63 years, have completed our inpatient program with pretest and discharge work performance assessment. Results showed that heart rate responses were decreased during the early stages of testing, when comparing discharge testing to postoperative findings. The duration of exercise increased from 12.6 minutes to 16.3 minutes ($P < .0004$), and the maximum work output increased from 17.1 watts to 23.5 watts ($P < .0004$). There was no significant morbidity associated with arm ergometry testing or the arm ergometry exercise training and rehabilitation program. We conclude that arm ergometry testing and training is a safe and effective method for improving the upper body muscular strength and efficiency of arm work in patients with recent vascular amputations.

Self-monitoring for Home Exercise Programs

The rate of perceived exertion (RPE) (Table 1) is an instrument for self-monitoring of exercise intensity, usually measured during exercise stress testing.[17] It has been described frequently in the cardiac rehabilitation and exercise literature and is generally felt to be a useful indicator of exercise intensity. This instrument can then be used for self-monitoring in subsequent training.[18,19] Because the aerobic training program commonly used in this patient group is arm ergometry, the RPE could potentially allow patients to indirectly monitor their training intensity without interrupting the exercise routine to measure pulse responses.

Finestone and colleagues studied the association between a patient's heart rate response and RPE using a graded arm ergometry test.[11] The patient population studied included severely deconditioned vascular amputees before and after an inpatient rehabilitation program. They studied 26 men at admission and 11 following completion of the program. Scatter plots and linear regression analyses revealed no statistically significant relationship either at early stages of exercise or at peak work for heart rate or RPE. These results suggest that the RPE should not be used as a substitute for direct pulse measurement in the exercise training of persons with recent vascular amputations.

TABLE 1.—*Borg Rating of Perceived Exertion Scale**

Borg Rating	*Perceived Exertion*
6	
7	Very very light
8	
9	Very light
10	
11	Fairly light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Very very hard
20	

*From Borg and Linderholm.[17]

The Influence of Cardiovascular Function on Walking After Vascular Amputation

Waters and co-workers studied the energy costs of ambulation in 70 patients with unilateral amputation (above the knee, below the knee, and Syme's).[20] Patients were tested on a treadmill at a "comfortable walking speed and at fast walking." Noted were higher metabolic costs (peak direct oxygen consumption) in patients with higher anatomic levels of amputation, advanced age, or a history of PVD.

Huang and associates studied the energy costs of ambulation in 25 normal controls, 6 with below-knee, 6 with above-knee, and 4 with bilateral above-knee amputations.[21] The patients were each requested to walk at their most comfortable speed. The investigators found increased energy expenditure in all amputees compared with controls. Those with bilateral above-knee amputations expended three times the energy for walking that normal controls did per meter distance. They concluded that these data need to be considered when prescribing a prosthesis for a person with bilateral above-knee amputations.

In a study of 37 persons with vascular amputations, van Alsté and colleagues reported that all patients with a maximum work capacity of greater than 60 watts per minute on discharge from rehabilitation achieved the ability to walk outdoors with their prosthesis compared with only 38% of patients with a lower work capacity.[14]

Cruts and co-workers studied 39 patients with lower extremity vascular amputations with resting ECG and rowing arm ergometry.[10] All patients had moderate to severe functional aerobic impairment on baseline exercise testing. Rowing arm ergometry was used to determine a safe maximal heart rate for exercise training early in their rehabilitation program. The investigators then correlated the results of baseline functional capacity evaluation with the patients' prosthetic success after rehabilitation. They found that 70% of those patients who achieved a peak work load of greater than 45 watts per minute at admission assessment were able to ambulate without an assistive device at discharge. Of those who failed to achieve a maximal work load of 45 watts per minute at admission, however, 38% were also able to ambulate without walking frames at discharge.

Moore and associates did a retrospective review of 157 patients following major lower extremity amputation for PVD.[22] They examined the association between a history of coronary artery disease and the achievement of household ambulation with a prosthesis. In all, 78% of those with above-knee amputations who failed to achieve household ambulation had a history of coronary artery disease. Only 7% of patients with above-knee amputations who ambulated had a history of coronary disease. Of patients with bilateral amputations who were not ambulatory, 73% had coronary artery disease compared with 20% of bilateral amputee ambulators. There was no difference in the prevalence rates of coronary disease between those with below-knee amputations who achieved or failed to achieve household ambulation. They concluded that the presence of coronary artery disease in elderly persons with above-knee or bilateral amputations because of vascular disease was associated with a decreased likelihood of household ambulation.

Conclusions

Coronary artery disease is prevalent in patients with lower extremity peripheral vascular disease, especially among those who go on to amputation. The use of dipyridamole-thallium imaging in these patients may improve the ability to diagnose asymptomatic coronary artery disease before initiating an exercise program, thereby allowing adequate treatment and preventing complications during rehabilitation. Arm ergometry is a safe and effective exercise alternative for detecting asymptomatic coronary disease in those unable to exercise their lower extremities and can be used to determine safe upper extremity exercise levels in poorly conditioned patients and those with known coronary disease. Arm ergometry testing is also useful for providing prognostic information concerning functional outcome after a rehabilitation program. Exercise testing is therefore indicated in all vascular amputee patients before beginning an exercise training and prosthetic rehabilitation program. Exercise training can safely and inexpensively enhance the functional capacity of amputee patients with PVD. More studies are needed to understand the full effects of exercise testing and training on specific cardiac variables, cardiovascular risk factors, and functional capacity for patients with PVD after amputation.

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